PROMPT/DELAYED GAMMA-RAY NEUTRON ACTIVATION ANALYSIS (PGAA/NAA) SYSTEM FOR TOTAL, NONDESTRUCTIVE, IN SITU, ELEMENTAL ANALYSIS USING A NEUTRON GENERATOR

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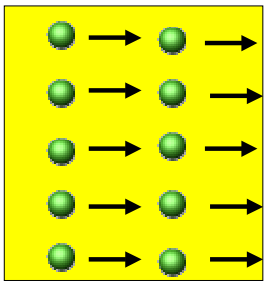


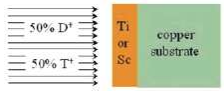
LBNL Neutron Generatror

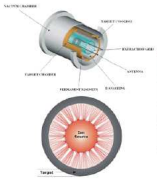
MODERATED THERMAL NEUTRONS

TARGET

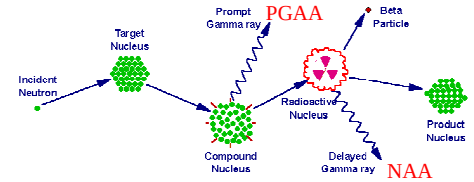
X(n,γ)

DETECTORS

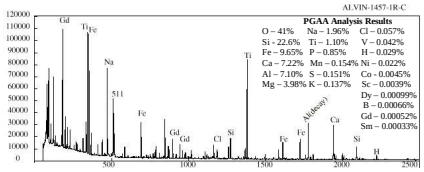




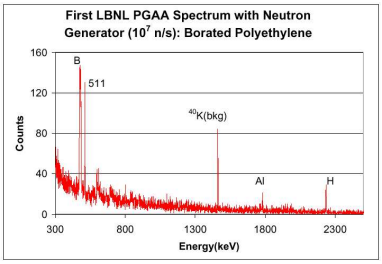
	D-D reaction	D-T reaction
Accelerator spec.	150 keV,1.5 A	120 keV,1 A
neutron yield [n/sec]	10^{12}	10^{14}
$\phi_{thermal}$ [n/cm^2/sec]	$1.5*10^7$	$5*10^8$



PGAA uses thermal neutrons to induce prompt γ rays, unique for every element, for quantitative analysis. This technique is simultaneously sensitive to the entire periodic table. Detection limits typically range from ppb to 0.1% depending on cross section. The γ rays from decay of radioactive products produced by NAA can also be used for analysis. PGAA can be used to interrogate sealed containers because neutrons penetrate most materials.

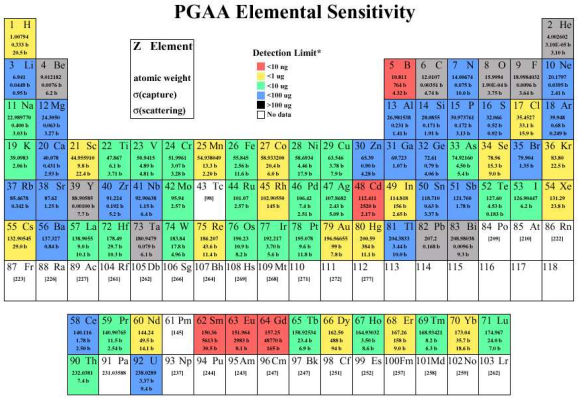


PGAA analysis of a deep-sea vent sample collected with the ALVIN submersible. Analysis was performed at the Budapest Reactor facility with a 10^6 n/s beam. Additional γ rays up to 9 MeV were observed. D.L.Perry, R.B. Firestone, *et al*, J. Anal. At. Spectrom. **16**, 1 (2001).



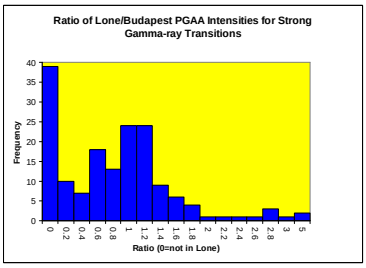
PGAA spectrum produced with prototype LBNL neutron generator.

PGAA Elemental Sensitivity



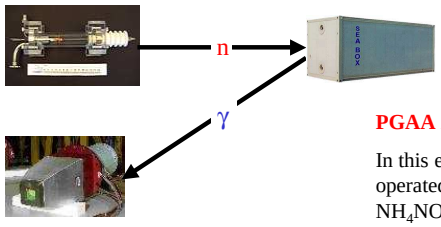
* Per cm³ based on 0.01 captures per second assuming 10^6 neutrons/cm² and neglecting gamma-ray detection efficiency.

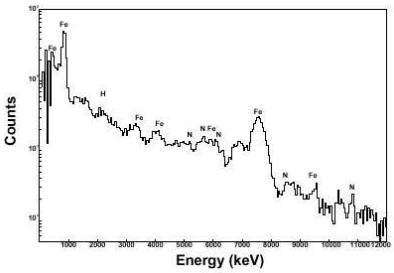
DATABASE: A new database of 33,000 γ rays for PGAA analysis is being prepared by LBNL in collaboration with the IAEA and the Institute for Isotope and Surface Chemistry, Budapest. This database replaces the outdated Lone *et al* data (At. Data Nucl. Data Tables **26**, 511(1981).)



Ratio of the strongest γ-ray intensities from our new compilation to those of Lone *et al*. About 25% of these γ rays were not observed by Lone.

SEARCHING FOR CONCEALED EXPLOSIVES





PGAA ANALYSIS OF A CARGO CONTAINER

In this example, the LBNL neutron generator is operated in D+D mode to detect 500 lbs of NH_4NO_3hidden in a cargo container. The γ-ray spectrum is calculated with the computer code MCNP assuming 2×10^9 incident neutrons are emitted next to a 40 ft cargo container. A single 6"x9" BGO detector is placed on the opposite side of the container. The 2.5 MeV neutrons from the source thermalize in theNH_4NO_3. This spectrum would be obtained in <0.1 s with a 10^{12} n/s LBNL neutron generator. The spectrum is dominated by the steel container walls, but gammas from nitrogen and hydrogen clearly visible.

Comparison of certified (NIST) and PGAA measured concentrations in river sediment

Element	CERTIFIED Concentration%	PGAA Concentration%
Cr	2.96±0.28	≡2.96
Fe	11.3±1.2	11.5±0.3
K	1.2	1.4±0.1
Ca	2.9	3.0±0.1
Cd	0.00102±0.00009	0.00104±0.00003
Mn	0.078±0.010	0.077±0.011

OTHER PGAA ANTITERRORISM APPLICATIONS:

- Forensic analysis of crime scenes
- Interrogation of nuclear materials
- Luggage screening
- Stand-off detection of explosives
- Landmine detection